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(54) ELECTRIC HEATING OF GASES

(71) We, FARBENFABRIKEN BAYER AKTIENGESELLSCHAFT, of 509, Leverkusen, Germany, a corporate body organised under the laws of Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method of, and an apparatus for, the electrical heating of gases or gaseous substances, for example vapours, using a reactor lined with a refractory, insulating material. The electrical heating of gases and vapours is frequently carried out with the aid of rod-shaped or tubular resistance heating elements around which, or through which, the gas to be heated flows. Arrangements of this kind are attended by the disadvantage that the heat-exchange surfaces are always relatively small so that, in practice, the process can only be carried out with gases of the kind that absorb radiation heat. However, it is possible to obtain large heat-transfer surfaces by using electrically heated moving or fluidised beds consisting of carbon or graphite or mixtures thereof with inert particles as the bed material, or of carbon, coke, graphite and so on in bulk, which are placed between the electrodes in such a way that the gas has to ascend through the electrically heated bulk material.

Unfortunately, these last two processes are also attended by disadvantages. In an electrically heated fluidised bed, the material used to make up the bed undergoes extensive abrasion, whilst the heating system has to be followed by a heated gas-purifying unit. The losses through abrasion are high, particularly in cases where carbon is used in admixture with a much harder inert material. In addition to this, there are limits to the throughput volume of gas because a fluidised bed of given dimensions is not universally applicable. On the contrary, the bed has to be accurately adapted to the particular reaction conditions.

The bulk bed made up of carbon or graphite in the form of large lumps is preferably used for reactors of relatively large dimensions. With relatively small reactors, the particle size of the bulk material has to be reduced accordingly to provide a large heat-exchange area. The result of this, at least in cases where the gas flows upwards, is that the particles of the bulk material no longer lie firmly and immovably on top of one another, but loosen up and move relatively to one another, even at relatively low rates of gas flow. If graphite spheres 10 mm. in diameter and a gas temperature of 700° C. are used, the "fluidising rate" is 4.5 m/sec. in the case of nitrogen, 3.0 m/sec. in the case of chlorine and even less in the case of metal chloride vapours. The "fluidising rate" is the rate of gas flow, calculated for the empty tube, at which the bulk material begins to loosen up and to move.

It is clear that the material begins to loosen at relatively low rates of gas flow. Once loosening begins, adequate contact is of course lost, resulting in arcs which can lead to serious disturbances. If the arcs occur near the wall, the wall material may begin to melt, leading to both encrustation of the bulk material and deterioration in current flow. Arc-induced overheating can also promote chemical reactions between the ceramic material of the lining and the carbon or graphite. If the material in question is one which contains silicon dioxide, reduction to SiO for example can take place, the SiO formed being converted back to SiO_2 at colder zones in the bed. As a result, a coating of SiO_2 is formed over the carbon and current flow becomes progressively worse, leading to a greater number of flashovers. Finally, current flow is impeded altogether or, due to encrustation, the flow of gas is complicated to a considerable extent, both resulting in frequent stoppage of the reaction.

We have now found that gases or gaseous substances such as vapours, for example, can be electrically heated if, in accordance with the invention, the gases or gaseous substances are passed through a packed bed of

granular, thermally and electrically conducting particles which is heated by the passage of an electric current through it and by the thermal conduction and radiation of a resistance heating element surrounded by the packed bed, so that the transfer of heat to the gas takes place largely through the packed bed, the resistance heating element being in electrical contact with the electrically conducting particles. As a result, an uninterrupted transfer of heat is obtained in the packed bed despite the use of a bulk material in the form of small chips to obtain a large heat-exchange surface, even in cases where the gas flows in an upward direction. In addition, the invention obviates contact difficulties within the bed so that no arcing occurs, and overheated zones within the bed are also avoided. In the event that the electrical contact becomes weak between the granules thereby producing high electrical potentials the electrical current via the electrical resistance elements is increased. Therefore electrical arcs are avoided. The process according to the invention is carried out with a reactor lined with an insulating, refractory material between whose gas-inlet and gas-outlet openings a packed bed of particles of carbon, graphite or a similar conductive material is arranged, surrounding and in electrical contact with at least one electrical resistance heating element provided with current leads which is electrically continuous throughout the reactor. The resistance heating element is with advantage held between two electrodes, at least one of which is movable, being provided with a resilient lead, i.e. to accommodate heat-induced expansion of the resistance heating element. The arrangement is such that the gas passes through the bed.

The resistance heating element preferably consists of a rod or tube of carbon, graphite or of a carbide which is inert with respect to the gas.

Since the flow of current is guaranteed by the incorporation of the resistance heating element, the packed bed may consist of particles of any size. They no longer have to lie on top of one another under their own weight to establish contact. On the contrary, the particles can be kept so small that the gas to be heated approaches the fluidising rate. The fact that there are no limits to the size of the particles has distinct advantages. In cases where graphite or a similar material is used to make up the packed bed, the particles will dissipate a considerable amount of the heat liberated in the resistance heating element, apart from a small radiation component, into the bed by virtue of their high thermal conductivity, so that the heat can be given up to the gas in the bed due to the large heat-exchange area available there. By virue of the freedom of choice in the size of the bed particles, it is also possible to vary the heat-exchange area within wide limits by varying the size of the particles in a reactor of constant dimensions (e.g. by decreasing uniformly the particles size along the flow path of the bed, the heating intensity may be increased from the inlet to the gas outlet). This factor is of particular importance in the heating of gases which themselves do not absorb any radiation heat because, in this case, the heat transfer area is of decisive importance so far as adequate heat transfer is concerned. However, the heat is not generated solely in the resistance heating element. The bed also has a current flowing through it by virtue of its electrically conductive contact with the heating element, so that it also heats itself. The portion of current flowing through the bed can amount to one-third for example. To compensate for any thermal expansion affecting the resistance heating element held between the electrodes, steps should be taken to ensure that the resistance heating element can be displaced relatively to the packed bed and hence relatively to the reactor, e.g. by movably mounting at least one of the electrodes and providing it with a resilient lead.

Since the uniform flow of current is guaranteed by the resistance heating element and since the bed particles do not have to be tightly packed, the apparatus described may be mounted in any spatial position. It may be operated downwards, upwards or even horizontally.

The process according to the invention is suitable for heating a variety of gases such as nitrogen, chlorine, hydrogen or metal and semi-metal halides, e.g. in vapor form, such as, for example, silicon tetrachloride, titanium tetrachloride, aluminium chloride and others. These preheated gases, e.g. at 250—800° C, may be used for instance in vapor phase oxidation processes such as disclosed in British Patent Application No. 16692/64 (Specification No. 1,062,579. The process is particularly suitable for gases which themselves do not absorb radiation heat, although the invention is not limited in its application to gases of this kind. The resistance heating element may be composed of a variety of materials such as, for example, metals or composite materials containing metals, carbon, graphite, carbides and/or similar conductive materials. Th bed materials selected should be suited to the gases to be heated and should be inert with respect to the tube or rod material at the temperatures prevailing, e.g. graphite, carbon, coke, etc. The lining of the reactor should also be chosen in such a way that the substances to be heated are inert thereto. Suitable lining materials include, for example, highly refractory oxide or silicate

materials, SiO_2 Al_2O_3, mullite, steatite or graphite. The process according to the invention and an embodiment of the apparatus in which it may be carried out are illustrated by way of example in the accompanying drawing in which Fig. 1 shows a longitudinal section of a reactor and Fig. 2 a transverse section taken along the line II—II of Fig. 1.

The heating zone consists of a cylindrical metal jacket 1 which is provided with a refractory, insulating lining 2, 3. A packed bed 4 (shown schematically) of graphite, carbon or the like, which surrounds a resistance heating element 5 fixedly connected at both ends with the electrodes 6 and 7, is arranged in the metal jacket. Whilst the electrode 7 is immobile, the electrode 6 is displaceable to compensate for any thermal expansion which may occur in operation. Expansion is absorbed by a resilient lead 8 which is fixedly connected with a double electrode terminal 9 passing through and insulated from the housing. The gas to be heated is supplied through a pipe 10. The hot gas emerges again at a point 11. The main part of the electrode 6, the resilient lead 8, the insulated electrode terminal 9 and the gas supply pipe 10 are accommodated in a widened section 12 of the apparatus. This section remains relatively cold and may be composed of a metal which is resistant to the gases to be heated.

At the bottom end of the heating zone, there is a perforated graphite ring 13 which retains the bulk material and through which the heated gas passes. Opposite the gas outlet 11 there is another outlet 14. The heated gas leaves the apparatus by both outlets. It is possible additionally to heat a part of the gas in an electric heater e.g. after the outlet 11, and to conduct the remainder of the gas via outlet 14. The two gas streams are then combined together at an intermediate temperature. A perforated plate 15 holds the packed bed in position at the top. It is provided internally with a bore hole through which the resistance rod or bar 5 extends. This plate enables the rod 5 and the electrode 6 to move without obstruction relatively to the bed 4.

The apparatus may be run on direct current or alternating current. In both cases, the housing may be earthed at one terminal. In cases where direct current is used, the electrode 6 and terminal 9, and the resilient lead 8, which is advantageously made of stranded wire or folded metal strips, will preferably be the voltage-carrying parts. In this case, the electrode 7 is conductively connected with the housing which in turn is earthed. If alternating current is used and if the housing is not intended to carry voltage, the electrode 7 will pass through and be insulated from the housing as shown.

The bed 4 of packing material is only shown schematically although it will be realized that the annular interior between rod 5 and lining 3 is meant to be filled substantially completely by the bed particles, e.g. carbon, graphite, coke, etc., and that such bed either may be subsantially moving or quiescent during gas flow therethrough. Naturally, the bed particles are formed of electrically and thermally conductive particles which are substantially inert to the heated gas yet which permit thermal conduction and radiation heat given off by the rod 5 to pass therethrough to heat uniformly the gas in addition to the heat given off to the gas by the electrical resistance heating of the bed particles themselves due to their random electrically conductive contact with said heating rod 5.

WHAT WE CLAIM IS:—

1. A process for the electrical heating of gases or gaseous substances, wherein the gases or gaseous substances are passed through a packed bed of granular thermally and electrically conducting particles heated by the passage of a current therethrough and by thermal conduction and radiation from a resistance heating element surrounded by the packed bed, the resistance heating element being in electrical contact with the electrically conducting particles and the transfer of heat to the gas largely taking place through the packed bed.

2. An apparatus for carrying out the process claimed in claim 1 comprising a reactor lined with an insulating, refractory material, wherein a packed bed of particles of carbon, graphite or a similarly electrically and thermally conductive material is arranged inside the reactor between its gas inlet and outlet openings in such a way that the bed surrounds and is in electrical contact with at least one resistance heating element provided with current leads which is electrically continuous throughout the reactor, the arrangement being such that the gas passes through the bed.

3. An apparatus as claimed in claim 2, wherein the resistance heating element is held between two electrodes, at least one of which is movable and is provided with a resilient current lead.

4. An apparatus as claimed in claim 2 or 3, wherein the resistance heating element consists of a rod or tube of carbon or graphite or of carbide which is inert with respect to the gases.

5. An apparatus as claimed in any of claims 2 to 4, wherein the particle size of the constituent material of the packed bed decreases in the direction of the flow of gases.

6. A process as claimed in claim 1, sub-

stantially as herein described with reference to the accompanying drawing.

7. An apparatus as claimed in claim 2, substantially as herein described with reference to the acc mpanying drawing.

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1215140 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

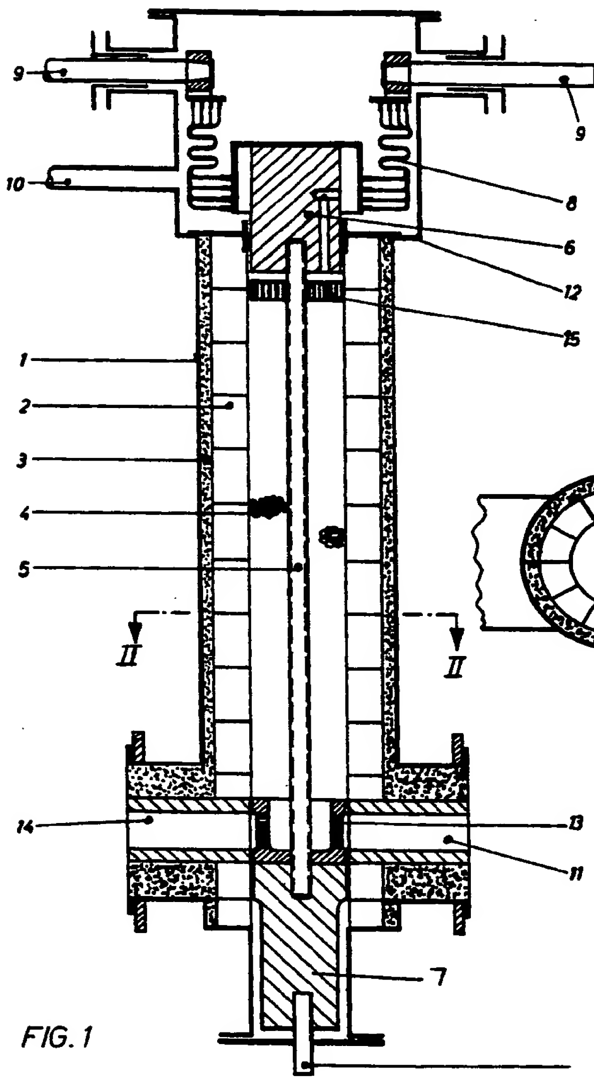

FIG. 1

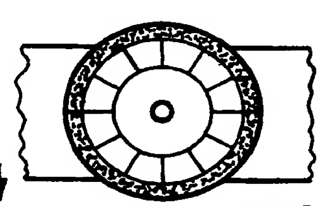

FIG. 2